Description

Method and device for emission of the exhaust gases from internal combustion engines in marine vessels into the water surrounding the marine vessels

The invention relates to a method for (in particular performance-improving) emission of exhaust gases from internal combustion engines in marine vessels into the water surrounding the marine vessels.

It is known for the exhaust gases from internal combustion engines in marine vessels to be introduced into the water surrounding the marine vessels, either in order to prevent visible emission of the exhaust gases (an exhaust-gas plume) or in order to make use of an extraction capability with the aid of existing waterjets. The extraction capability for exhaust gases through the outlet opening of the waterjet flow from the hull of a marine vessel is known, for example, from US Patent Specification 4,979,917. However, this has the disadvantage that the internal combustion engine has to operate against the hydrostatic pressure of the water as a back-pressure, that is to say its performance is reduced. This performance reduction is particularly major in the case of boosted diesel engines, whose exhaust-gas turbines are highly sensitive to back-pressure. For this reason, the exhaust gas from a boosted internal combustion engine is passed according to the proposal in DE 103 14 057 B3 into the snorkel tube of the submarine, in which the boosted internal combustion engine is arranged. However, this solution requires a very high degree of hardware complexity and increases the power requirement of the submarine when snorkeling, since the snorkel tube must be designed to be correspondingly more voluminous.

The object of the invention is to specify a method and a device which make it possible to achieve a considerable performance

improvement in comparison to the prior art, in comparison to the previous extraction methods for exhaust gases from internal combustion engines in surface vessels or submarines. The object

is achieved in that the exhaust gases and a water flow which is taken from the surrounding water are mixed with one another in a dedicated device in a reduced-pressure field, with the reduced pressure for the reduced-pressure field being produced by a reduction in the cross-sectional area of the water flow before mixing. The water flow is in this case simply produced in a pump upstream of the device.

The combination of a reduced-pressure field for the exhaust gas with a mixer for exhaust gas and water results surprisingly, in a possible improvement in the performance, which is considerable in particular in the case of submarines. For surface vessels, this results in the advantageous capability to emit the exhaust gases relatively deep under the water surface. This prevents the possibility of the exhaust gases being detected, thus resulting in the exhaust gases being emitted in a so-called "signature-free" manner from marine vessels, including submarines.

The "signature-free" emission of exhaust gases from submarines is known from DE 100 61 487 C1. However, a considerable amount of external energy is required in this case in order to overcome the static pressure of the water surrounding the marine vessel or a not inconsiderable decrease in performance must be accepted. As already mentioned, long exhaust-gas pipes are required in or on the snorkel tube in order to avoid this.

The emission of exhaust gases outside the hull of a marine vessel under water is known per se, for example from WO 93/07053. However, no mixing takes place in this case, but two flow elements are produced which run parallel without being mixed, in which case the corresponding device must be located only relatively slightly below the water. Further under water emission devices for exhaust gases are also known, for example from JP-2001/239995 A which, like a large number of similar solutions, discloses an ejector for exhaust gases. An ejector

such as this requires a considerable amount of external energy and does not lead to the desired mixing of the exhaust gas and water, since the highly accelerated,

dense waterjet is not mixed with the gas that is supplied coaxially, and enters the water surrounding the marine vessel virtually unchanged, without actually conveying the gas.

The disadvantages described above are avoided by the method according to the invention and the device according to the invention.

One advantageous refinement of the invention in this case provides for the reduction in the cross-sectional area of the water flow to be carried out in such a manner that an accelerated water flow is formed in the shape of a hollow cylinder, and in such a manner that the exhaust gases are introduced into the interior of the hollow-cylindrical water flow. This results in a reliable conveying effect for the gas which, advantageously interacting with the annihilation of the annular structure of the water flow at a short distance downstream from the mixing device, leads to a two-phase exhaust-gas/water mixture, which can no longer be detected.

A further refinement of the invention provides for the exhaust gases also to be passed to the outside of the hollow-cylindrical water flow. This embodiment of the method is particularly advantageous when very large exhaust-gas flows are involved, that is to say for example when the internal combustion engine is a gas turbine.

A further refinement of the invention provides for the hollow-cylindrical water flow to be caused to rotate, for example by swirl producing means, such as blades, and for the exhaust gas also to be caused to rotate in the opposite direction to the hollow-cylindrical water flow, for example likewise by swirl producing means, such as blades. This results in the capability to produce the desired two-phase mixture over a very short movement distance through a guidance tube at or on the marine

vessel. Furthermore, this results in a particularly fine and uniform distribution of the

exhaust gas in the water and in the ideal case even in a homogeneous mixture.

One refinement of the invention in this case provides for the exhaust-gas flow to be caused to form a hollow-cylindrical shape, for example by means of a displacement body in the exhaust-gas flow. This advantageously makes it possible to produce an axial flow within the mixing device without any reverse flow, as is advantageous for mixing and production of reduced pressure.

A further refinement of the invention provides for the exhaust gas to be cooled to below 100 degrees C, for example by means of water injection, in order to reduce its volume before being introduced into the reduced-pressure field. This measure, which is known per se in naval vessels makes it possible to reduce the gas volume to such an extent that it is possible to use the conventional pipe diameters on submarines for the device, for example with an external diameter of 250 mm. At the same time, this highly advantageously prevents the formation of a three-phase mixture, for example composed of exhaust gas, steam and water, which is difficult to cope with.

A further refinement of the invention provides for the exhaust gas to be subjected to a pressure rise following the mixing with the water flow and after passing through the reduced-pressure field, for example in a widened exhaust-gas outlet pipe with a diffuser effect. A considerable diffuser effect, which generally increases the pressure to a sufficient extent, is intrinsically provided in the device, downstream from the displacement body used according to the invention. In accordance with the requirements, this can, if required, be even further increased simply by further widening of the mixture outlet pipe. This allows exhaust-gas outlet depths of more than 5 m to be achieved.

In order to carry out the method for emission of exhaust gases from internal combustion engines in marine vessels into the water surrounding the marine vessels, a device is provided which

is in the form of an exhaust-gas/water mixer and has a reduced-pressure chamber. The performance-increasing exhaust-gas emission can thus advantageously be carried out with its further advantages.

One refinement of the invention in this case provides for a guidance device for the water to be arranged upstream of the reduced-pressure chamber in the flow direction, having an annular cross section so that a hollow-cylindrical waterjet is formed. This results in the formation of a waterjet, which allows the exhaust gas to be incorporated into the waterjet particularly advantageously. This reliably allows the extraction of the exhaust gas, and prevents the water and gas from being extracted into the surrounding water in an unmixed form.

A further refinement of the invention provides for a guidance device for the exhaust gas to be arranged upstream of the reduced-pressure chamber in the flow direction and to have an annular cross section, so that the exhaust gas also flows out in the form of a hollow cylinder. This highly advantageously results in two flow elements with large surfaces, which are extracted in a mixed form despite the major density differences between the two media.

A further refinement of the invention provides for the guidance device for the water to have guidance elements, in particular blades with a cycloid shape, by means of which the water can be caused to rotate. This results in an advantageous rotational movement of the water with little drag, if the exhaust-gas flow is caused to rotate in the opposite direction by appropriate guidance elements, that is to say in particular also blades with a cycloid shape, decisively improving the mixing of the two flow elements, and forming a homogenous exhaust-gas/water flow shortly downstream from the guidance device.

The water flow which is taken from the surrounding water is optionally produced by means of a radial pump or by means of an axial pump. A radial pump is appropriate when the pump is arranged, for example, on the free shaft end of a diesel engine, since

this results in a particularly space-saving device, which is particularly advantageous for submarines. An axial pump can advantageously be used when additional guidance elements are provided which make use of the motion of the marine vessel through the water and take a flow element which has already been speeded up to the speed of the marine vessel. Furthermore, an axial pump such as this can be arranged immediately upstream of the mixing device, thus resulting in the water flowing into the mixing device without any deflection. The rotational movement of the axial pump can also be used to produce swirl, but the installation complexity is greater than that for the arrangement of a radial pump on the free shaft end, for example of a diesel engine.

It is generally sufficient for the drive power of the pump for the water flow to be 20-30 kW, in order to allow exhaust gas to be emitted at normal pressure at a water depth of 5 m from a diesel engine of more than 1000 kW. However, the performance improvement for this engine is several hundred kW.

A pump with a central shaft or else an external rotor may be used as the axial pump. This must be matched to the respective space conditions in the marine vessel.

One particularly preferred refinement of the invention provides for the mixing device to have an inner displacement body for the gas flowing to it. This advantageously also provides a hollow-cylindrical shape for the gas flow, and at the same time to prevent the gas/water mixture that is formed in the mixing device from flowing back into the guidance elements for the water flow and the gas flow. This advantageously results in reliable operation both for the production of the reduced pressure and for the mixing process.

The gas and water flows are advantageously introduced into the device via coaxial pipes for gas and water thus at this stage

forming the annular shape for the gas flow and the

water flow. This results in particularly advantageous flow conditions in the mixing device.

A cooling device for the exhaust gas considerably reduces its volume, so that the device according to the invention can be physically relatively small and may, for example, have an external diameter of 250 mm. In particular, this takes account of the space requirements in a submarine.

The device according to the invention has shut-off means, which can be subjected to open-loop and closed-loop control, with monitoring devices which are advantageously connected in particular to the marine vessel control system or to the engine control system. A reliable locking circuit for the shut-off means can thus then be formed, and account can also be taken of the starting dynamics of the internal combustion engines and of the mixing device and outlet apparatus. In addition, non-return valves, in particular with position monitoring, are provided so that, overall, the same safety can be achieved for a submarine or for a surface vessel as that without the use of the device.

The method according to the invention and the device according to the invention are advantageously intended for use not only for submarines when snorkeling but also for surface vessels with internal combustion engines distributed in the marine vessel, in particular for internal combustion engine/generator sets distributed in the marine vessel. When used in submarines, the device is advantageously arranged at the stern end of the vessel in the wake of the fin or of the fin lower structure, and can optionally be integrated in the outer casing of the submarine, or can be designed such that it can be moved out of it. If arranged at the stern of the vessel in the wake from the fin or from the fin lower structure, it is particularly advantageous that the device does not produce any additional drag and is even used in an area of the submarine in which there is a

turbulent flow, which assists the introduction of the two-phase mixture that is formed into the surrounding water.

When used for surface vessels, it is particularly advantageous for the devices each to be arranged with the internal combustion engines which are provided for them in different vessel safety areas. For surface vessels, such as corvettes or frigates, this then not only results in signature suppression of the exhaust gas, but also in a safety level which complies with the safety for, for example, fuel-cell systems which are arranged at a different point in the marine vessel. Interchangeability is thus possible. For surface vessels, it is particularly advantageous in this case, and in some circumstances for underwater vessels as well, for the other exhaust gases that are produced in the marine vessel, for example the exhaust air from an air-conditioning system or the reformer exhaust air from fuel-cell systems, to be mixed with the exhaust gas from the internal combustion engines. This is advantageously possible because the exhaust gases are in fact discharged at a reduced pressure, that is to say no external energy is required for compression of the exhaust gases in order to emit them into the surrounding water.

The invention will be explained in more detail with reference to drawings from which, in the same way as for in the dependent claims, further details of an inventive nature will become evident.

In detail:

Figure 1 shows a schematic longitudinal section through an exhaust-gas mixing and reduced-pressure device,

Figure 2 shows a 3D illustration of the mixing blades with the central displacement body, seen from the outlet side, and

Figure 3 shows the speed distribution of the two flow elements in the device, on a calculated basis.

In Figure 1, 1 denotes the housing pipe of the exhaust-gas emission line device, which is at the same time the pipe for introduction for the

mixing and reduced-pressure production water. 2 denotes the gas pipe and 3 denotes the central displacement body, which is advantageous and significant to the invention, for gas and water. The reduced-pressure region according to the invention is formed on the outside of the widened area 4 around the displacement body 3. Guidance elements 5 and 6 are provided in order to introduce swirl into the water flow and gas flow, and can at the same time form a holder for the displacement body 3 and the widened water channel 4. The water which is supplied to the mixing and reduced-pressure production device is symbolized by the arrows 7, and the gas is symbolized by the arrow 8. The two-phase mixture that is formed is symbolized by the double-headed arrow 9.

The geometric relationships, that is to say the pipe diameters and the pipe section lengths in the device, are a quite major factor of the advantageous operation of the mixing and reduced-pressure production device. For this reason, Figure 1 shows the individual lengths and the main diameters. The relationships between the dimensions in Figure 1 are as follows:

DA = 1.5 - 2.0 D4
L1 = 3 - 4.5 D4
L2 = 0.6 - 0.8 D4
L3 = 0.8 - 1.2 D4
L4 = 0.6 - 1.0 D4
L5 = 1.3 - 1.7 D4
L6 = 1.5 - 3.5 D4
D1 = 1.2 - 1.5 D4
D2 = 0.2 - 0.3 D4
D3 = 0.2 - 0.3 D4
D4 is the diameter of the exhaust-gas pipe

The relationships shown in the table are calculated for an exhaust-gas pipe with a diameter of 250 mm, in which the exhaust gases from a typical, boosted submarine diesel are

emitted into the surrounding water. A boosted diesel with exhaust-gas turbo chargers and a power of 1300 kW is regarded

as a typical diesel. The exhaust-gas inlet temperature to the device is 90 degrees C, after it has been cooled as provided according to the invention. When the two-phase mixture of gas and water is introduced and the device is arranged in the wake of the submarine fin, or of a similar device on board the submarine, no additional measures are required for a good transition between the two-phase mixture and the surrounding water.

If installed at a different point on the submarine, or if installed in underwater emission systems of surface vessels, an additional guidance element may also be advantageous in order to produce a water flow with appropriate suction.

In Figure 2, 10 denotes the central displacement body and 11 the swirl producing elements, in this case cycloid blades, for production of swirl in the water, and 12 denotes the swirl producing elements which are located further inwards, in this case also cycloid blades, for the gas. The blade shape is in this case chosen so as to produce only a small amount of axial drag. The displacement body 10, which is lengthened to the rear, prevents reverse flow of the gas and of the water into the area of the swirl producing elements, and ensures reliable operation of the reduced-pressure mixing device. Other blade shapes may be chosen instead of the cycloid shape. This depends on the mixing/drag ratio which is intended to be achieved.

Figure 3 shows the various speeds of the two media of gas and water in the emission device, with the gray shade showing the different speeds. The speed of the water is at a minimum in the dark area 13, and increases in the area 14, as can be seen from the lighter gray, until a speed decrease with a pressure increase finally occurs in the area 15. The inlet-flow gas in the light area 16 is at its normal "exhaust" speed and is likewise highly accelerated on the displacement body. Finally,

relative matching occurs with a particularly slow flow in the outlet-flow area from the displacement body in the area 18, the outlet-flow area from the device. Swirling results in good mixing in this area 15, 18, so that the water-flow stability that occurs in the case of ejectors or waterjets undoubtedly does not occur. In fact, this results in a real two-phase mixture with a reduced pressure for the gas flowing out in the area 17, which results in the desired performance improvement, according to the invention, for boosted diesel engines. 19 denotes the diffuser area, in which the pipe diameter may be increased even further.

The relationships illustrated in the figures and which are shown in the table relating to Figure 1 can be applied over a wide power range of internal combustion engines. The 1300 kW diesel that is used as the basis for calculation represents approximately the mid-range of the application area. Both considerably larger boosted diesel engines and smaller diesel engines can be operated with the same relationships for the device according to the invention. There are no limits at the bottom end of the performance of the corresponding internal combustion engines. Even gas turbine exhaust gases can be emitted in a similar manner under water, with a performance improvement.